EFFECT OF FUEL SPRAYS ON EMISSIONS*

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This program is aimed at operating a research gas turbine combustor under realistic conditions such that the influence of individual variables (in particular, fuel spray characteristics) on emissions can be determined. The special combustor allows independent control over drop size, fuel-air ratio, air inlet temperature, pressure, reference velocity, and residence time. Also, it lends itself to theoretical modeling and turbulent intensity measurements through use of laser velocimetry.

The combustor utilizes 37 needles for liquid fuel injection wherein each is surrounded coaxially with the primary airflow. Control of the air velocity largely determines the Sauter mean diameter (SMD) of the resultant spray. Other major components of the facility are the high pressure air supply, the air preheater, an enclosure for elevated pressure operation, and the exhaust system. A water cooled sampling probe, with steam heat to ensure sample integrity, is used for collecting the sample for the emissions instrumentation. Validity of the emissions results is tested by using the results in a comprehensive data analysis program to calculate the input fuel-air ratio. Comparison of this value with measured input values, along with the calculated summation of mole fractions, offers a good check on the measurements.

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An approximate one dimensional analysis of the combustor behavior, along with some kinetic implications, is briefly mentioned. This work has been published elsewhere [1,2] and hence no details are given here. Also, a few laser doppler velocimetry determinations of turbulence level and flow velocity have been presented elsewhere [3] and are only briefly mentioned. Some calculations on the influence of residence time, drop size distribution, and gas properties on the emissions index are presented and discussed.

The main results of this paper are in the form of emissions results for a range of operating conditions. A number of graphs are presented and discussed which show the variations of emissions levels with one variable at a time, among those variables listed in paragraph one. In every case the fuel is Jet A, the pressure is atmospheric, and combustion is restricted to a primary zone.

A short movie of the combustor in operation is shown.

References

1. Patil, P.B., Sichel, M., and Nicholls, J.A., "Analysis of Spray Combustion in a Research Gas Turbine Combustor," Combustion Science and Technology, Vol. 18, 1978, pp. 21-31.

2. Patil, P.B., Sichel, M., and Nicholls, J.A., "Calculation of CO Concentration for Liquid Fueled Gas Turbine Combustor," presented at Central States Section, The Combustion Institute, Purdue University, April 3-5, 1978.

3. Driscoll, J.F. and Pelaccio, D.G., "Laser Velocimetry Measurements in a Gas Turbine Research Combustor," presented at the Third International Workshop on Laser Velocimetry, Purdue University, July 1978.

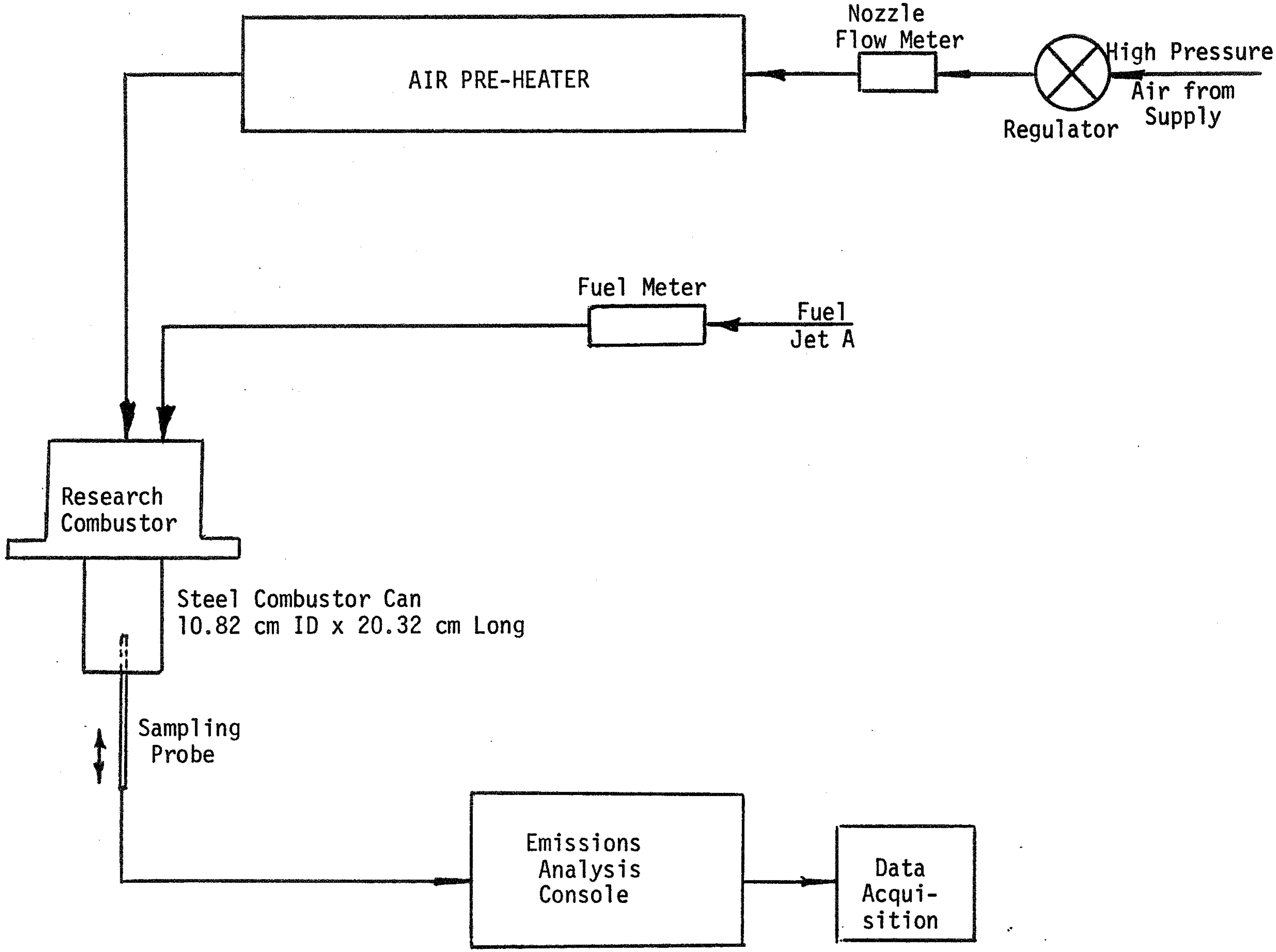


Figure 1. Schematic of Flow System

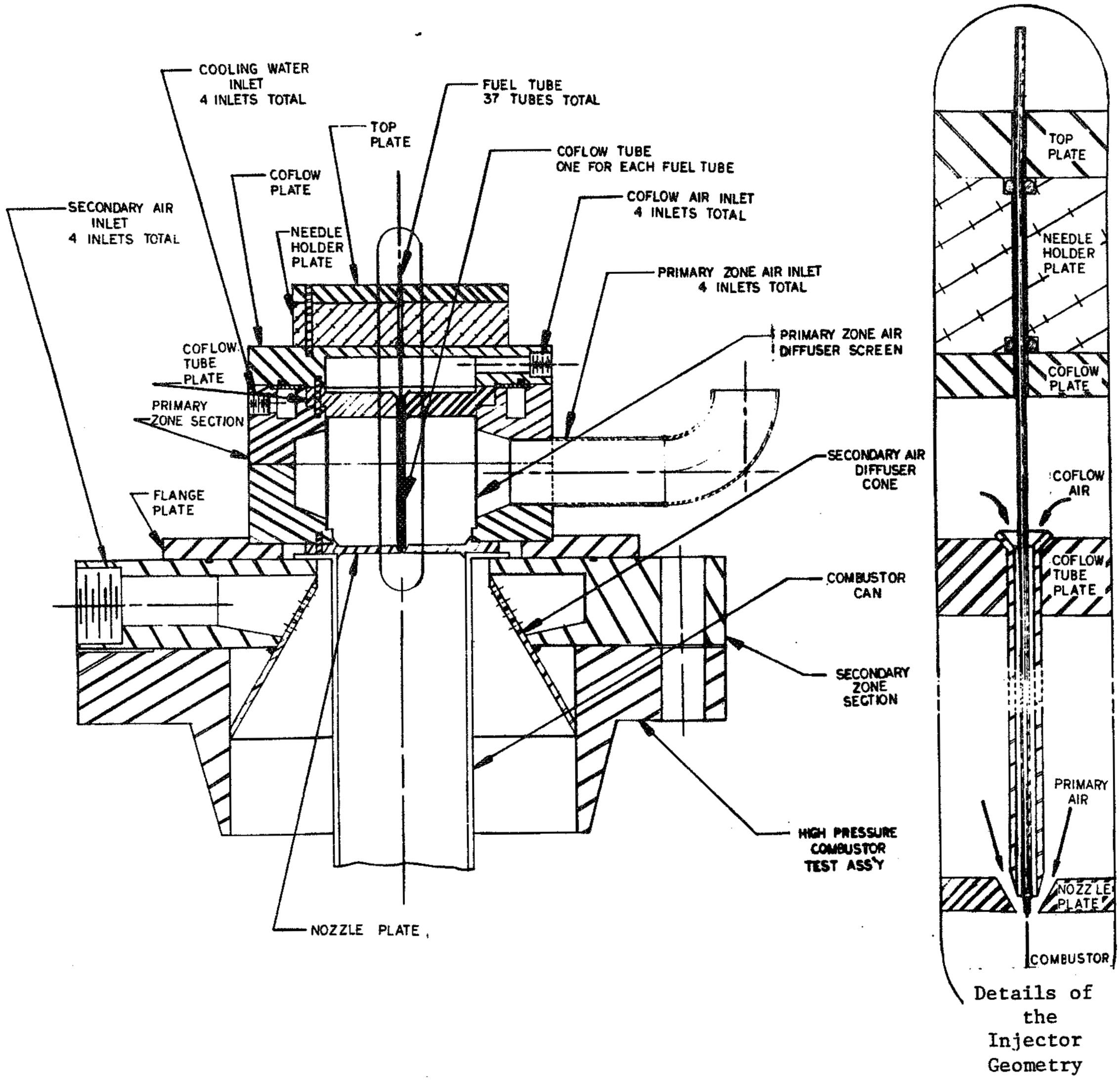
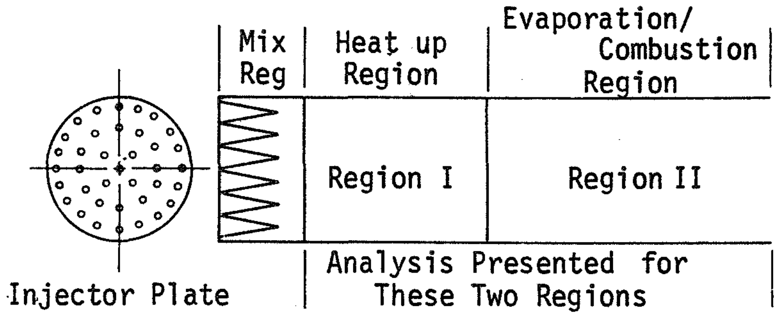


Figure 2. Fuel Droplet and Air Preparation System and Combustor.



$\lambda_1 = k_1\lambda$ $\qquad\qquad$ $\lambda_2 = k_2\lambda$

λ = laminar coefficient of heat conduction

k_1, k_2 related to scale and intensity of the turbulence

u_1 = burning velocity

$u_1 \propto 1/r$ $\qquad$ Effect of drop size

$u_1 \propto (k_1 k_2)^{-1/2}$ $\qquad$ Effect of turbulence

Figure 3. One Dimensional Analysis

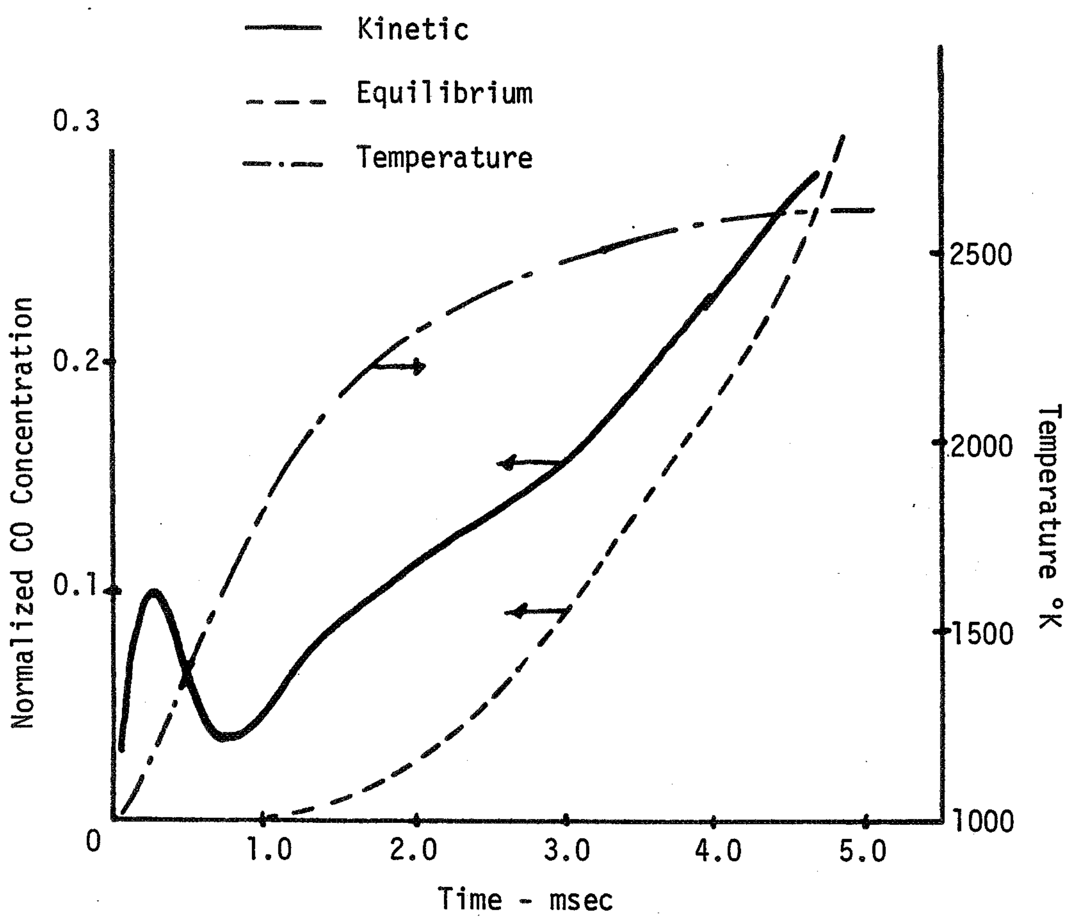
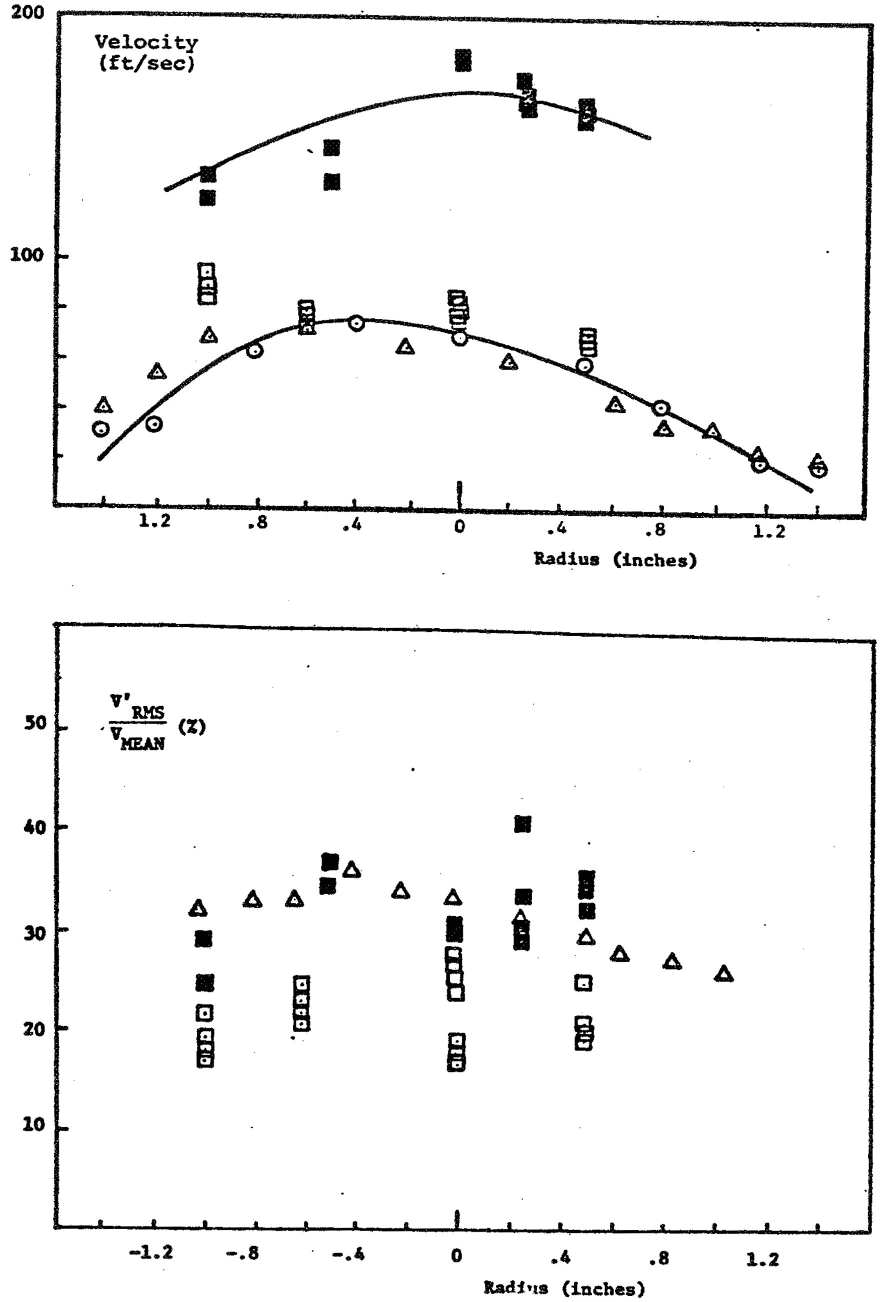


Figure 4. Inaccuracy of the Local Equilibrium Assumption for CO Concentration



ϕ = 0.9

P = 1 atm

$\dot{m}$ = .158 lbm/sec

■ LDV Hot Flow

□ LDV Cold Flow

O Pitot Cold Flow

Δ Hot Wire Cold Flow

Figure 5. Laser Velocimetry Measurements

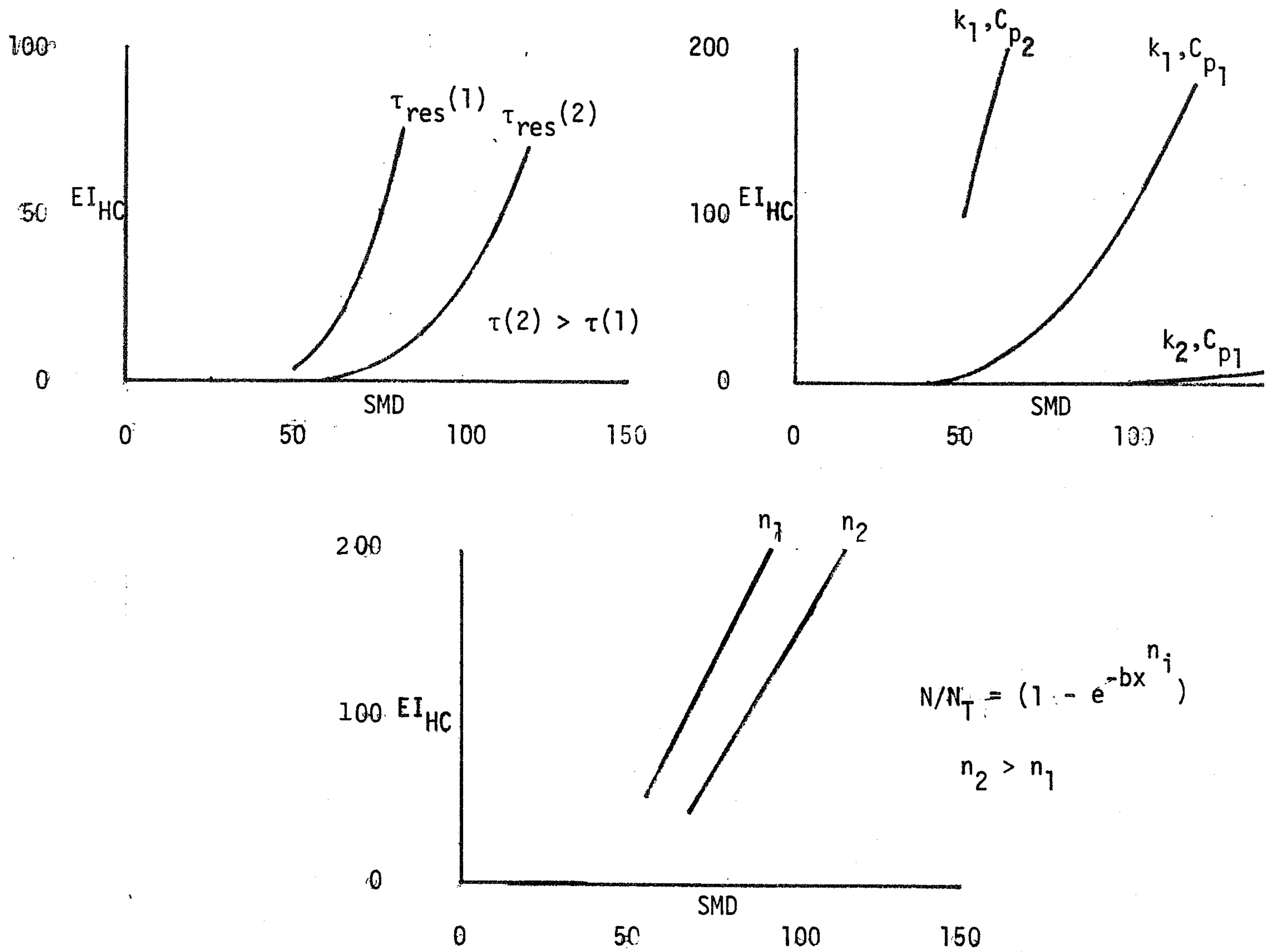


Figure 6. Influence of Residence Time, Gas Properties, and Drop Distribution Function on Emissions Index.

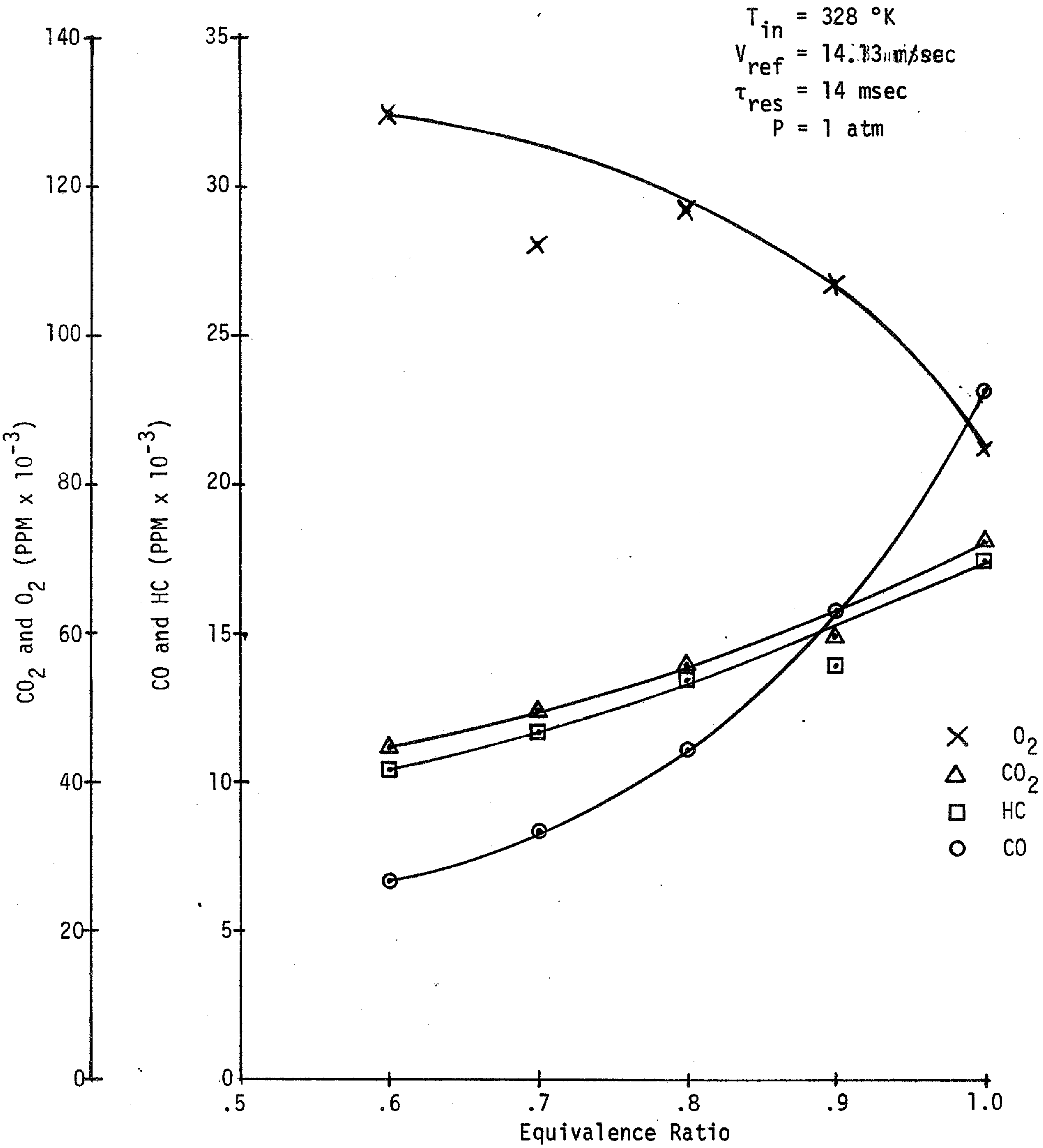


Figure 7. Emissions Variation with the Equivalence Ratio